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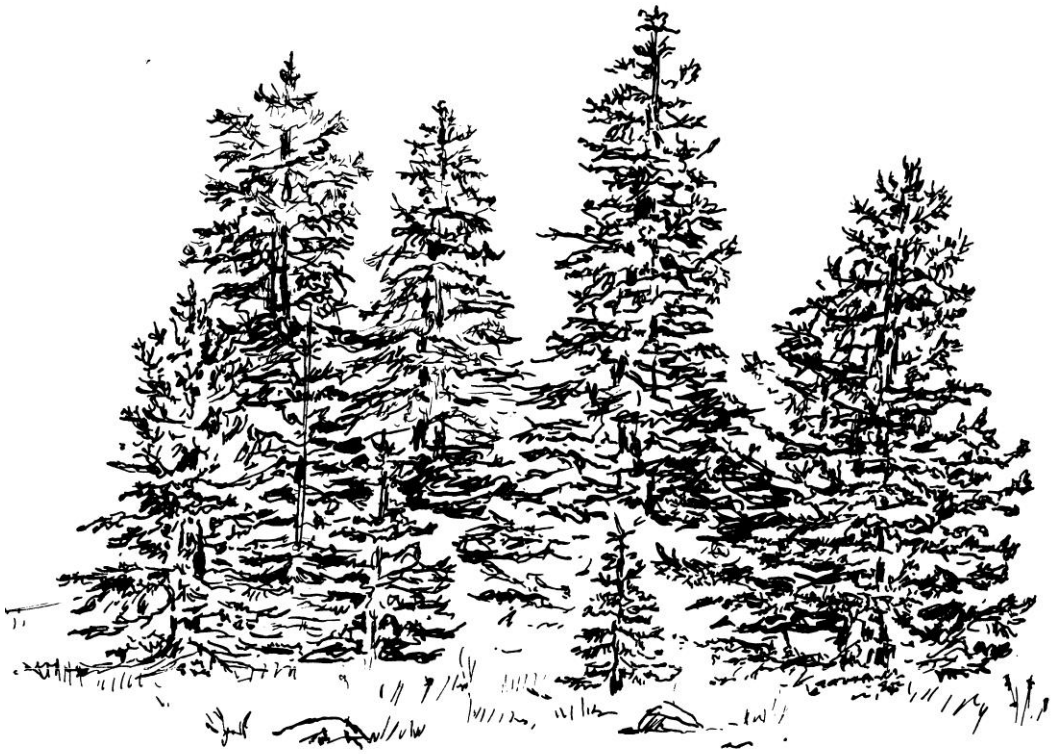
STAND SUSCEPTIBILITY RATING SYSTEM
CENTRAL IDAHO FORESTS
USER'S GUIDE for the
Forest Vegetation Simulator



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SSRS

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INTRODUCTION

The purpose of the Stand Susceptibility Rating System for the Forest Vegetation Simulator (SSRS-FVS) is to help land managers identify areas where stand conditions are favorable to the major forest insects and pathogens in southern Idaho forest ecosystems. By using these susceptibility ratings, forest managers can better prioritize susceptible stands for analysis and potential treatment before an outbreak develops.

Over the years and in different forums, hazard/susceptibility and risk/vulnerability definitions have become interchanged causing confusion. For the purpose of this user's guide, we define them as the following:

Hazard/Susceptibility Definition
Hazard, or susceptibility, is defined as the stand conditions that predispose forested acres to insect and disease activity. Stand conditions are measured using specific criteria; many are common among agents. Conditions such as stand density, stand structure, tree size, and quantity of host can predispose a stand to insect and disease disturbance. These conditions are the foundation of most rating systems and can be calculated for individual stands in FVS.

Risk/Vulnerability Definition
Risk, or vulnerability, is defined as the percent of mortality or growth loss from an outbreak and are not addressed by this document. Susceptibility models presented in this user's guide do not estimate amount of potential loss resulting from agent activity or predict when an outbreak may impact a particular stand. There are other models to estimate this loss for some agents.

Other Factors
Other conditions that cause tree stress at the stand or landscape level include wind events, severe drought, fire injury, and impacts from multiple agents acting on the same host. These are also very important to stand dynamics; unfortunately these interactions are not easily measured or modeled and are not included in these hazard ratings.

Three factors influence insect and disease outbreaks that may impact forest resource values: 1) susceptible hosts, 2) disturbance agent populations, and 3) favorable weather conditions. This document describes a method to characterize the condition of the susceptible hosts at the stand level for major forest insects and dwarf mistletoes found in southern Idaho (Table 1). Because agent populations can differ dramatically from year to year due to host availability, natural enemies, weather events, etc., factors 2 and 3 are not accounted for in these ratings. Users should contact the Forest Health Protection-Boise Field Office, or other appropriate forest health specialists, to assess factors 2 and 3 as part of the project planning and implementation process or assistance with the FVS loss models.

Table 1. List of susceptibility ratings for insect and pathogen agents and associated result variable name displayed in FVS output. The category value will be next to the result variable name in the output and then user translated to a low, low-moderate, moderate, or high susceptibility category.

Agent	**Result Variable Name**
Douglas-fir beetle	XDFBtl
Western pine beetle in mixed-conifer stands	XWPBt-M
Western pine beetle in plantations or 2nd growth ponderosa pine stands	XWPBt-P2
Mountain pine beetle in lodgepole pine	XMPB-LP
Mountain pine beetle in ponderosa pine stands	XMPB-PP
Mountain pine beetle in whitebark and limber pine	XWBBtl
Combined host pine beetle	XCBBtl
Spruce beetle in Engelmann spruce	XSBES
Western spruce budworm/Douglas-fir Tussock Moth	XBw
Dwarf mistletoe in Douglas-fir, lodgepole, ponderosa pine, and western larch	XDFMst XPPMst XLPMst XWLMst

How to use this Guide

Measurements for estimating stand condition can be collected using stand inventory protocols and entered into appropriate database systems. In Region 4 of the U.S. Forest Service, most stand and forest inventory examinations are stored in the FSVEG database. Data can be extracted and processed through the Forest Vegetation Simulator (FVS) growth simulation model so that individual tree information can be computed and summarized at the stand level. The FVS simulator can project stand conditions such as growth, age, density, average diameter, mortality, and stand structure over many cycles in a planning horizon. These stand conditions are the basis for measuring susceptibility to change agents.

In order to use SSRS-FVS, you will need to have the FVS software (Dixon 1990) using the Suppose Interface (Crookston 1997) installed on your PC. You can find these on the FVS website (http://www.fs.fed.us/fmsc/fvs/). A working knowledge of how to extract inventory data from FSVEG into FVS format and run FVS using the Suppose interface system is required for successful use of the SSRS-FVS.

The susceptibility rating schemes are coded into a text file called a .kcp file (addfile) that can be added to an FVS simulation using the Suppose interface program. The user should contact the Forest Health Protection (FHP) Office to obtain the appropriate and most current file that is suitable for the FVS variant in use, or on the Region 4 FHP website: http://www.fs.usda.gov/detail/r4/forest-grasslandhealth. Not all rating schemes included in the .kcp file need to run for all stands. Consult FHP as you cut and paste the specific agent ratings needed to describe your stands. FVS has a limit on the total number of things that can be computed per run. Very complicated runs may result in unprocessed addfiles. If the addfiles do not run, try each rating separately in FVS. Additionally, remember that the ratings will be invoked only if the stands meet the minimum requirements detailed in this guide, ex. the required species and density.

The output created by the Event Monitor in a FVS run can be extracted with the Compute post processor and saved in text file with a ".cp1" extension or directly written to an Access database or Excel file. The data stored in either of these files can be used as an input for other computer software for further analysis.

In summary, the steps are to:

1. Obtain current stand exam or other forest inventory data.
2. Process data through a translator program to create input for FVS.
3. Obtain a .kcp file that contains the susceptibility rating criteria (i.e. R4-SSRS-FVS_AllPests_CI_v2.kcp).
4. Add the .kcp file to the FVS simulation using the Suppose interface.
5. Run FVS to generate the ratings and save them to a file with the Compute post processor (.cp1) or write directly from FVS to an Excel file (.xls) or an Access database (.mdb).
6. Repeat Steps 2-5 for each of the treatment alternatives for comparison among treatments.

RUNNING SSRS-FVS USING SUPPOSE

Once you have the software and stand data installed:

-Start **Suppose**
-Select the stands you wish to process and set up all keywords, outputs, and post processors for your analysis

To create the Compute 1 output file you must:

Select **Post Processor** from the main menu

From the **Available Post Processors** drop down menu:

Select **Compute1 – Table of Compute Variables (with headers)**
Select **Include**
Select **Close** and return to the main window

All the computed variables, including any you have added, can be viewed when the Compute 1 table opens after the run is complete.

To write to your database file:

-Select **Select Outputs** from the main window in Suppose
-Select **Database Extension**
-Select **Specify Output Database**

You can change the default name of the database but keep the .xls extension.

-Select **OK**
-Select **Event Monitor (EM) Compute Variables**
-Select **Build Compute Table in Database**

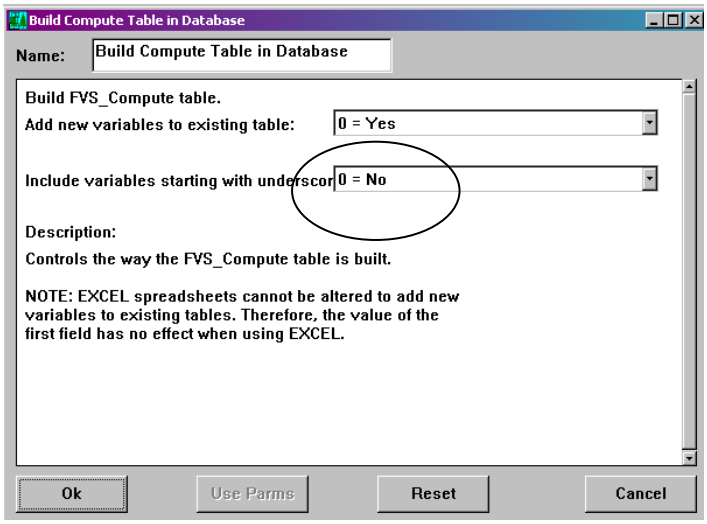

Figure 1. Suppose window for sending computed variables to a database.

If you wish to see all the computed variables in the database, change the No in the second drop down box to "1 = Yes" as indicated in Figure 1. This will include the intermediate variables,

i.e., those starting with underscore. Be aware that there may be many computed variables. To see only the susceptibility results, accept the default of "0=No".

-Select **OK**
-Select **Close**

Add the keyword file with the susceptibility rating schemes:

-Select **Insert from File** from the main window in Suppose
-Navigate to the **R4-SSRS-FVS.kcp** file and **Open**
-Select **Close**

Now select **Run Simulation**. After the simulation has completed, watch for the Table of Computed Variables window. It may open after you close several other post processor windows.

A REAL WORLD EXAMPLE: UNDERSTANDING RATING STRUCTURE WITH A DISCUSSION ON INTERPRETATION, LIMITIATIONS, AND OTHER CONSIDERATIONS

Each rating has a set of stand conditions used to assess whether impacts of any particular agent could move from "low" to "high" levels. The measurements for these stand conditions are translated into attributes that can be calculated from the input data in the stand exam. These attributes are categorized using criteria associated with agent host preference and assigned an associated numeric rating value of 0.1, 1, 2, or 3. The Douglas-fir beetle (DFB) rating (Table 2) is used in this example, but the principles are similar for the other models and the process is the same.

In this example stand, the QMD of Douglas-fir that are greater than or equal to 9 inches is 13.55 inches; the stand basal area per acre of all live trees is 105 sq. ft.; and the proportion of basal area of the Douglas-fir trees greater than or equal to 9 inches is 0.63, or 63% (Displayed in the second column of Table 3). The "arrow" from Table 2 to Table 3 indicates that in this instance the QMD value falls in the "Range between low and high" and the associated number value is displayed in the column in Table 3. This process is then repeated for the other measurement attributes.

Table 2. Example using the Douglas-fir beetle hazard rating.

Description of Measurement	**Measurement Attribute**	**Criteria and Associated Values**			
		0.1	**1**	**2**	**3**
Inter-Tree Competition	Basal area of all tree species per acre	< 60 sq. ft.	≥60 and ≤120 sq. ft.	≥120 and <220 sq. ft.	≥ 220 sq. ft.
Agent host preference	QMD of Douglas-fir ≥ 9 inches DBH		< 10 inches	≥10 and <14 inches	≥ 14 inches
Quantity of suitable host available	Proportion of basal area of Douglas-fir ≥ 9 inches DBH	0.01 to 1.00			

Table 3.Example stand data and associated numeric values.

Description of Measurement	**Measurement Attribute**	**Computed data from FVS of example stand**	**Criterion Met**	**Associated numeric Value**
Inter-tree Competition	Basal area of all tree species	105 sq. ft.	≥60 and ≤120 sq. ft.	1
Agent host preference	QMD of Douglas-fir ≥ 9 inches DBH	13.55 inches	>10 and <14 inches	2
Quantity of suitable host available	Proportion of basal area of Douglas-fir ≥ 9 inches DBH	0.63	0.63	0.63

These associated rating values are then used in a multiplicative formula to produce a stand susceptibility result.

_valSUS1=*Inter-tree competition rating value* X *Agent host preference rating value* X *Quantity of suitable host proportion*

Example Rating Values **Stand Susceptibility Result(_valSUS1)**

1 X 2 X 0.63 = 1.26

Then the stand susceptibility rating result is categorized as shown in Table 4 by the highlighted row.

Table 4. Douglas-fir Beetle Categories.

Susceptibility Result	Category Value in XDFBTL	Susceptibility Category
< 1.2	1	Low
≥1.2 <2	1.5	Low-Moderate
≥2 <3	2	Moderate
≥3 <4	2.5	Moderate-High
≥4	3	High

Because the Susceptibility Result is between 1.2-1.99, the Category Value of "1.5" is displayed in the XDFBTL column (Figure 2, indicated by arrow). In this example for the Year 1995, the "Susceptibility Category" for this stand would be a "Low-Moderate." This "Low-Moderate" rating reflects the low basal area in this stand which estimates low competition between the trees even though the stand is mostly susceptible Douglas-fir trees (63% of stand basal area) and of suitable size as estimated by the QMD rating.

As shown in the Compute 1 table (Figure 2) in this example, the Susceptibility Result (_VSLSUS1 column) precedes the Susceptibility Category column (XDFBTL) which starts with an X (see Table 1 in the Introduction for a complete list models). Variables used to show the measurement attribute and associated rating values will begin with an underscore. All variables for a susceptibility model will be grouped together. It is easiest to find the susceptibility result variable in the list (i.e., _VALSUS1) and work backwards. Note that the variable _BAStand is listed only once at the beginning of the table in the column list but is used in the majority of the ratings. Variable names and definitions are listed in Appendix A.

Stand ID: 0402050052260053
Mgmt ID: NONE

YEAR	_PROPPBA	_BWBAHST	_BASTAND	_DFQMD1	_DFPROP1	_VALBA1	_VALQMD1	_VALSUS1	XDFBTL
1995	0.00	101.78	105.43	13.55	0.63	1.00	2.00	1.26	1.50
2000	0.00	108.11	111.70	14.10	0.63	1.00	3.00	1.88	1.50
2010	0.00	120.33	123.70	15.24	0.62	2.00	3.00	3.72	2.50
2020	0.00	129.63	132.67	16.41	0.62	2.00	3.00	3.71	2.50
2030	0.00	137.50	140.27	17.57	0.62	2.00	3.00	3.70	2.50
2040	0.00	144.44	146.95	18.73	0.61	2.00	3.00	3.67	2.50
2050	0.00	150.91	153.18	17.83	0.66	2.00	3.00	3.94	2.50
2060	0.00	155.96	158.02	16.28	0.76	2.00	3.00	4.53	3.00
2070	0.00	160.76	162.56	17.38	0.76	2.00	3.00	4.58	3.00
2080	0.00	164.73	166.25	18.46	0.77	2.00	3.00	4.61	3.00
2090	0.00	167.60	168.86	18.74	0.79	2.00	3.00	4.76	3.00
2100	0.00	169.26	170.33	19.25	0.81	2.00	3.00	4.85	3.00

Figure 2. Example of Compute 1 table from FVS.

Depending upon project objectives, a potential next step in the interpretation would be to evaluate how this stand progresses through time and the resulting changes in DFB susceptibility. In Figure 2, the FVS simulation was initiated in 1995 and displayed the associated values at the beginning of each decade through 2100. In 1995 and 2000 the stand was at a "Low-Moderate" rating. From 2010 through 2050 the stand was in a "Moderate-High" rating. And, from 2060 – 2100 this stand had a "High" rating of susceptibility for DFB. Even though the basal area criteria did not make the highest rating, the relatively high proportion of suitable host and the large tree size of the stand resulted in the "High" DFB susceptibility rating by Year 2060.

A common application is to manipulate stand conditions to see how disturbance events or treatments affect susceptibility. This can be done by doing a model run without the event, then comparing a model run with the management or disturbance event. Or if stand data are from 1995 the stands could be grown until 2010 and the "FVS DFB mortality" model can be run to emulate the changes of a known DFB outbreak. Often times these alternatives are displayed in colored maps of the stands across the landscape or in tabular form. This can be especially useful when showing the differences in highly susceptible acres between a "No Action" and "Action" alternatives.

Limitations and Considerations

There are some limitations and considerations the user should be aware of due to bark beetle behavior, in particular, how they respond to individual tree or landscape characteristics. In general, the bark beetles rated in this document prefer to attack large, mature to overmature host trees that are stressed within a stand. This behavior is reflected in the stand susceptibility rating systems. However, the factors measured in these ratings are at the stand level and not at the individual tree or landscape levels. Bark beetle attacks could be expected when host trees are clumped within a stand, local competition around an individual tree is high, or a tree has been damaged. Thus, even stands with a "Low" susceptibility rating could have bark beetle activity due to the characteristics of individual trees.

Additionally, host conditions in adjacent stands may indirectly increase the susceptibility of a stand by providing a landscape of highly susceptible stands and potentially high beetle populations; or conversely, a stand surrounded by a landscape of non-host stands may have the overall susceptibility lowered. While these ratings do not deal with this issue of scale directly, integrating these results with geographic information systems (GIS) enables mapping of forested areas to identify concentrations of highly susceptible stands. These "hazard maps" are often useful in discussing large landscapes with varying levels of susceptibility and to prioritize treatment areas to meet land management objectives. For example, when high-hazard stands are intermixed with low-hazard stands, beetle population many not be as active. Low-hazard stands may have host tree components, but are either not of high enough quality or in large enough quantity to allow beetle population to remain at high levels. Therefore, for instance, mountain pine beetle may still cause significant mortality in the pine components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazard stands are clustered.

A common issue that could arise when modeling a "thinning from below" silvicultural treatment is an increase in a stand's susceptibility to bark beetles in decades following treatment. This is often the result of the post-treatment, residual stand having only large host trees remaining. In this scenario, the removal of the smaller trees was not effective enough in lowering the competition factor (stand density measured by basal area) to lower the overall susceptibility rating. An additional complication is often the non-host trees are selected for removal. The residual stand is then comprised mostly of host trees. Convention would indicate that the trees in the individual stand would have a lower susceptibility with the decrease in competition, even though the overall stand susceptibility rating may have increased. At the individual tree level, characteristics of being mature to overmature may begin to override the stand factors that would influence bark beetle behavior.

As for all of these susceptibility rating schemes, the results should be discussed with a forest health specialist, entomologist or pathologist, for further interpretation, and current insect or disease population levels that may impact other management considerations.

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DOUGLAS-FIR BEETLE IN DOUGLAS-FIR RATING

Douglas-fir Beetle (DFB), *Dendroctonus pseudotsugae* Hopkins, is a bark beetle that primarily attacks Douglas-fir trees in the larger size classes. Healthy trees may successfully pitch out beetles that have entered through the bark unless trees are stressed (Furniss and others 1979; Rudinsky 1966). Outbreaks often develop after some type of major disturbance such as a wind event or fire (Furniss 1979). There are several studies that suggest that stand conditions like stand basal area and average diameter class of Douglas-fir can be used to predict DFB activity and impacts (Negron and others 1999; Weatherby and Thier 1993). This rating criteria is similar to Randall and Bush (2010) and Steele and others (1996).

Measurements

Inter-tree competition for nutrients, water, and light with other trees contribute to the stress of the host trees within a stand. Density of the trees in a stand is measured in square feet of basal area and is used to estimate the competitive stress. Basal area of less than 120 square feet per acre decreases susceptibility; and a stand with more than 220 square feet per acre increases susceptibility. Stand densities of less than 60 square feet of basal area are generally considered too open to have inter-tree competition interactions on most sites.

Agent host preference for DFB is measured using the quadratic mean diameter (QMD) of Douglas-fir greater than or equal to 9 inch DBH in a stand. If the QMD of these host trees is less than 10 inches, susceptibility is decreased. If it is greater than 14 inches, susceptibility is increased.

The final measurement is host quantity. Since Douglas-fir beetle prefers larger trees, the suitable host (Douglas-fir trees that are greater to or equal to 9 inches DBH) basal area in square feet is divided by the basal area of all trees (trees > 0.1 inches DBH) to calculate the stand proportion of suitable hosts.

Computing the Susceptibility Result for Douglas-fir beetle

Names of Triggers and Variables associated with the .kcp file calculations and output:

XDFBtl	Susceptibility category result for DFB
_dfqmd1	QMD for Douglas-fir ≥ to 9 inch DBH
_DFProp1	Proportion of Douglas-fir ≥ to 9 inch DBH
_valba1	Rating value of total basal area (0.1, 1, 2, 3)
_valqmd1	Rating value of QMD (1, 2, 3)
_valSUS1	Rating result or product of the multiplicative formula

The stand susceptibility result is computed using the following multiplicative formula:

_valSUS1=*Inter-tree competition rating value* X *Agent host preference rating value* X *Quantity of suitable host proportion*

The stand susceptibility calculation will produce a result within a range of 0.01 to 9.00. The susceptibility result has a corresponding category value that is displayed in XDFBtl column and is associated with a susceptibility category (Table 6).

Table 5. Rating for Douglas-fir Beetle.

Description of Measurement	Measurement Attributes	Criteria and Associated Values				Example Rating
		0.1	1	2	3	
Inter-tree Competition	Basal area of all tree species	< 60 sq. ft.	≥60 to <120 sq. ft.	≥120 to <220 sq. ft.	≥ 220 sq. ft.	Example Rating 225 sq. ft. of **BA=3**
Agent host preference	QMD of Douglas-fir ≥ 9 inches DBH		< 10 inches	≥10 and <14 inches	≥ 14 inches	Example Rating **QMD=2**
Quantity of suitable host available	Proportion of basal area that is Douglas-fir ≥9″DBH	0.01 to 1.00				Example Rating **Prop. of BA=0.45**
Susceptibility Result Example Rating (3 x 2 x 0.45 =**2.7**) Then, from Table 6, Susceptibility Category=**Moderate**						

Table 6. Susceptibility result, corresponding model value and susceptibility category for the Douglas-fir beetle rating.

Susceptibility Result _valSUS1	XDFBTL Value	Susceptibility Category
< 1.2	1	Low
1.2-1.99	1.5	Low-Moderate
2-2.99	2	Moderate
3-3.99	2.5	Moderate-High
≥4	3	High

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WESTERN PINE BEETLE IN PONDEROSA PINE RATINGS

Western pine beetle (WPB), *Dendroctonus brevicomis* LeConte*,* often attacks and kills ponderosa pine in groups of host of similar age in areas with high density. The behavior of the WPB in even-aged stands of mostly ponderosa pine is sometimes different from behavior in ponderosa pine in mixed-conifer, multi-age stands. Hessburg and others (1999) recognized these different behaviors and set the thresholds for the host age differently to capture those differences. As a result, the following two ratings have evolved to accommodate this beetle's complicated behavior. These ratings are similar to the Steele and others (1996) with modification from Hessburg and others (1999).

In a third scenario of single-tree or small groups of large, mature ponderosa pines, individual tree characteristics may affect WPB behavior. This scenario is not estimated well with these stand level rating systems. For individual tree susceptibility rating systems, see Miller and Keen (1960). Johnson (1972) demonstrated that this individual tree rating system could be applicable in other parts of the WPB range.

Rating 1: Western Pine Beetle in Stands with High Proportion of Ponderosa Pine

In many studies, highly dense groups of ponderosa pine trees of similar age and size are most susceptible to WPB (Demars and others 1982). These may be classified as plantation-like or second-growth stands. Densely stocked even-aged stands provide a higher outbreak potential. Ratings can be assigned as 0.1, 1, 2, or 3. The following individual rating criteria are applied to the model when the proportion of ponderosa pine is greater than 80 percent.

Inter-tree competition for nutrients, water, and light contribute to the stress of trees within a stand. Stand density is measured in square feet of basal area. Basal area of a stand with less than 80 square feet is considered to decrease susceptibility, but a stand with more than 120 square feet is considered increase susceptibility. Stand densities of less than 60 square feet of basal area are generally considered too open to have inter-tree competition interactions on most sites.

Agent host preference for WPB is measured using the quadratic mean diameter (QMD) of ponderosa pine trees ≥ to 5 inches DBH. If the QMD of these host trees is less than 8 inches, the stand is rated least susceptible; but if it is greater than 12 inches it is rated most susceptible.

In Rating 1, ponderosa pine consists of 80 percent or more of the stand. The proportion of host in square feet of basal area is computed for ponderosa pine ≥ 5 inches DBH. This is divided by the basal area of all trees > 0.1 inches DBH.

Rating 1: Computing the Susceptibility Result for Western Pine Beetle in Stands with a High Proportion of Ponderosa Pine

Names of triggers and variables associated with the .kcp file calculations and output:

XWPBt-P2	Susceptibility category result for WPB in even-aged, second growth ponderosa pine
_PPqmd3	QMD for ponderosa pine ≥to 5 inch DBH
_PPProp3	Proportion of ponderosa pine ≥to 5 inch DBH
_valba3	Rating value of total basal area (0.1, 1, 2, 3)
_valqmd3	Rating value of QMD (1, 2, 3)
_valSUS3	Rating result or product of the multiplicative formula

The stand susceptibility result is computed using the following multiplicative formula:

_valSUS3 = *Inter-tree competition rating value* X *agent host preference rating value* X *Quantity*

of suitable host available proportion

The stand susceptibility calculation will produce a result within a range of .08 to 9.0. The susceptibility result has a corresponding category value that is displayed in XWPBt-P2 column and is associated with a susceptibility category (Table 10). Be aware that as stand conditions change during your planning horizon, the rating method (or criteria) may switch between Rating 1 and Rating 2 for WPB. See the example in Figure 3.

Table 7. Rating 1: Western pine beetle in stands with high proportions of ponderosa pine.

Description of Measurement	**Measurement Attributes**	**Criteria and Associated Values**				**Rating**
		0.1	**1**	**2**	**3**	
Inter-tree Competition	Basal area of all tree species	< 60 sq. ft.	≥60 to <80 sq. ft.	≥80 to <120 sq. ft.	≥ 120 sq. ft.	Example Rating **BA=2**
Agent host preference	QMD of ponderosa pine ≥ 5 inches DBH		< 8 inches	≥8 to <12 inches	≥ 12 inches	Example Rating **QMD=3**
Quantity of suitable host available	Proportion of basal area that is ponderosa pine ≥5"DBH	≤ 0.80				Example Rating **Prop of BA=0.80**
Susceptibility Result Example Rating (2 x 3 x 0.80 =**4.8**) Then, from Table 8, Susceptibility Category=**High**						

Table 8. Susceptibility result, corresponding rating value and susceptibility category for the western pine beetle in ponderosa pine model 1.

Susceptibility Result _valsus2	**XWPBt-P2 Value**	**Susceptibility Category**
< 1.2	1	Low
1.2-1.99	1.5	Low-Moderate
2-2.99	2	Moderate
3-3.99	2.5	Moderate-High
≥4	3	High

Rating 2: Western Pine Beetle in Mixed-Conifer Stands with Ponderosa Pine

In mixed-conifer stands, western pine beetle often seeks out old and mature ponderosa pines of appropriate age and size. This rating criteria is used if proportion of host is less than or equal to .80. The proportion of host in square feet of basal area is computed for ponderosa pine ≥ 5 inches DBH. This is divided by the basal area of all trees > 0.1 inches DBH.

Competition measured in square feet of basal area is assigned low susceptibility when it is less than 80 square feet and high susceptibility when it is greater than 120 square feet. Total basal area of less than 60 square feet is considered too low to support large populations of WPB and receive a corresponding low associated value of 0.1.

Stands with QMD of ponderosa pine less than 12 inches DBH are a low susceptible value and stands that have a QMD of greater than or equal to 20 inches are rated as high susceptible value. The individual rating can be assigned as 0.1, 1, 2, or 3. The following individual rating criteria is applied to Rating 2.

Computing the Susceptibility Result for Rating 2: Western Pine Beetle in Mixed-Conifer Stands with Ponderosa Pine

Names of triggers and variables associated with the .kcp file calculations and output:

XWPBt-M	Susceptibility category result for western pine beetle in mixed-conifer, all age ponderosa pine
_PPqmd4	QMD for ponderosa pine ≥ to 5 inches DBH
_PPProp4	Proportion of ponderosa pine ≥ to 5 inch DBH
_valba4	Rating value of total basal area (0.1, 1, 2, 3)

The stand susceptibility result is computed using the following multiplicative formula:

_valSUS4 = *Inter-tree competition rating value* X *Agent host preference rating value* X *Quantity of host available proportion*

The stand susceptibility calculation will produce a result within a range of 0.08 to 9.00. The susceptibility result has a corresponding category value that is displayed in XWPBt-M column and is associated with a susceptibility category (Table 10). Be aware that as stand conditions change during your planning horizon, the rating method (or criteria) may switch between Rating 1 and Rating 2. See the example in Figure 3.

Table 9. Rating 2, Western pine beetle in mixed-conifer stands with mature and old ponderosa pine.

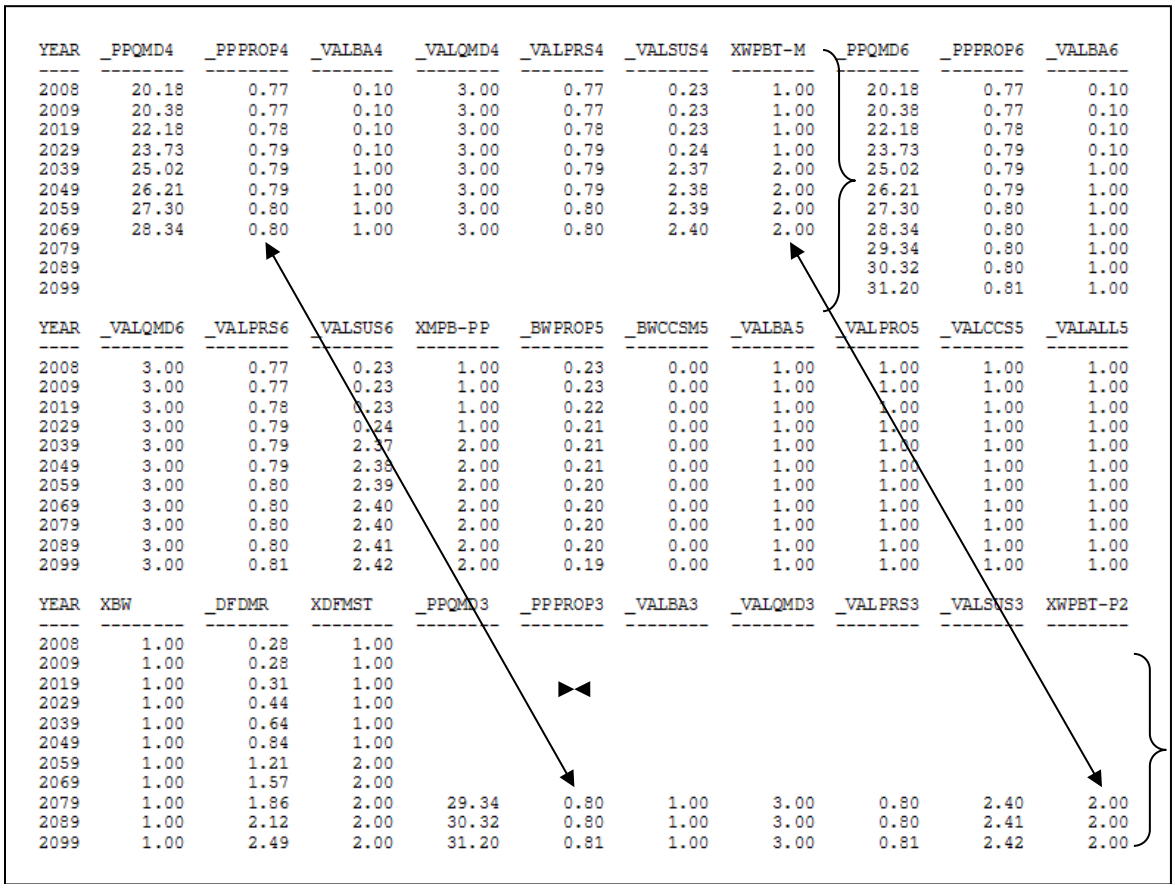
Description of Measurement	Measurement Attributes	Criteria and Associated Values				Rating
		0.1	1	2	3	
Inter-tree Competition	Basal area of all tree species	< 60 sq. ft.	≥60 to <80 sq. ft.	≥80 to <120 sq. ft.	≥ 120 sq. ft.	Example Rating **BA=3**
Agent host preference	QMD of ponderosa pine ≥ 5 inches DBH		< 12 inches	≥12 to <20 inches	≥ 20 inches	Example Rating **QMD=3**
Quantity of suitable host available	Proportion of basal area that is ponderosa pine ≥5"DBH	≤ 0.80				Example Rating **Prop of BA=0.41**
Susceptibility Result Example Rating (3 x 3 x 0.41 =**3.7**) Then, from Table 10, Susceptibility Category=**Moderate-High**						

Table 10. Susceptibility result, corresponding rating value and susceptibility category for western pine beetle in mixed-conifer stands with mature and old ponderosa pine.

Susceptibility Result _valsus4	XWPBt-M Value	Susceptibility Category
< 1.2	1	Low
1.2-1.99	1.5	Low-Moderate
2-2.99	2	Moderate
3-3.99	2.5	Moderate-High
≥4	3	High

Understanding the Output for Rating 1-XWPBT-M and Rating 2-XWPBT-P2

The rating method (or criteria) may switch the rating between WPB Model 1 (**XWPBT-M**) and WPB Model 2 (**XWPBT-P2**) as the proportion of ponderosa pine moves greater than, or less than or equal to .80 (indicated by the arrow on the left in Figure 3). The rating method correspondingly shifts as appropriate. These results will be reported in different locations in the Compute 1 table as shown in Figure 3. Also, the FVS outputs may show 0.80 in several cycles due to rounding (i.e. 0.79899 is rounded up to 0.80 in 2069; and 0.802324 is rounded down in 2079). The values written directly to the .xls output file by FVS will have more significant digits and rounding concerns can easily be verified there.



YEAR	_PPQMD4	_PPPROP4	_VALBA4	_VALQMD4	_VALPRS4	_VALSUS4	XWPBT-M	_PPQMD6	_PPPROP6	_VALBA6
2008	20.18	0.77	0.10	3.00	0.77	0.23	1.00	20.18	0.77	0.10
2009	20.38	0.77	0.10	3.00	0.77	0.23	1.00	20.38	0.77	0.10
2019	22.18	0.78	0.10	3.00	0.78	0.23	1.00	22.18	0.78	0.10
2029	23.73	0.79	0.10	3.00	0.79	0.24	1.00	23.73	0.79	0.10
2039	25.02	0.79	1.00	3.00	0.79	2.37	2.00	25.02	0.79	1.00
2049	26.21	0.79	1.00	3.00	0.79	2.38	2.00	26.21	0.79	1.00
2059	27.30	0.80	1.00	3.00	0.80	2.39	2.00	27.30	0.80	1.00
2069	28.34	0.80	1.00	3.00	0.80	2.40	2.00	28.34	0.80	1.00
2079								29.34	0.80	1.00
2089								30.32	0.80	1.00
2099								31.20	0.81	1.00

YEAR	_VALQMD6	_VALPRS6	_VALSUS6	XMPB-PP	_BWPROP5	_BWCCSM5	_VALBA5	_VALPRO5	_VALCCS5	_VALALL5
2008	3.00	0.77	0.23	1.00	0.23	0.00	1.00	1.00	1.00	1.00
2009	3.00	0.77	0.23	1.00	0.23	0.00	1.00	1.00	1.00	1.00
2019	3.00	0.78	0.23	1.00	0.22	0.00	1.00	1.00	1.00	1.00
2029	3.00	0.79	0.24	1.00	0.21	0.00	1.00	1.00	1.00	1.00
2039	3.00	0.79	2.37	2.00	0.21	0.00	1.00	1.00	1.00	1.00
2049	3.00	0.79	2.38	2.00	0.21	0.00	1.00	1.00	1.00	1.00
2059	3.00	0.80	2.39	2.00	0.20	0.00	1.00	1.00	1.00	1.00
2069	3.00	0.80	2.40	2.00	0.20	0.00	1.00	1.00	1.00	1.00
2079	3.00	0.80	2.40	2.00	0.20	0.00	1.00	1.00	1.00	1.00
2089	3.00	0.80	2.41	2.00	0.20	0.00	1.00	1.00	1.00	1.00
2099	3.00	0.81	2.42	2.00	0.19	0.00	1.00	1.00	1.00	1.00

YEAR	XBW	_DFDMR	XDFMST	_PPQMD3	_PPPROP3	_VALBA3	_VALQMD3	_VALPRS3	_VALSUS3	XWPBT-P2
2008	1.00	0.28	1.00							
2009	1.00	0.28	1.00							
2019	1.00	0.31	1.00							
2029	1.00	0.44	1.00							
2039	1.00	0.64	1.00							
2049	1.00	0.84	1.00							
2059	1.00	1.21	2.00							
2069	1.00	1.57	2.00							
2079	1.00	1.86	2.00	29.34	0.80	1.00	3.00	0.80	2.40	2.00
2089	1.00	2.12	2.00	30.32	0.80	1.00	3.00	0.80	2.41	2.00
2099	1.00	2.49	2.00	31.20	0.81	1.00	3.00	0.81	2.42	2.00

Figure 3. Example of Compute 1 table from FVS showing the location of XWPBT-M and XWPBT-P2.

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MOUNTAIN PINE BEETLE IN LODGEPOLE PINE RATING

Mountain pine beetle, (MPB), *Dendroctonus ponderosae* Hopkins, is a major agent of change in lodgepole pine forests. Outbreak populations of MPB can build rapidly causing large numbers of tree mortality. As much as 70% mortality in lodgepole pine over a broad landscape can occur over a short period of time (Bentz and Endreson 2003). The quality and the quantity of susceptible pine will influence mortality levels during an outbreak. The quality of the pine component of a stand as a MPB food source is best characterized by stand density and phloem thickness. Since phloem thickness is not generally measured in inventories, DBH, QMD and other available stand characteristics are used as surrogates. The quantity of the food source refers to the species composition and density of the forest. A pure, well stocked pine stand will be more likely to support a large MPB population than a mixed species and/or poorly stocked stand. The location of a stand also has a bearing on MPB success.

The basic stand conditions for used this rating are 1) average diameter of the host species; 2) density of the stand in square feet of basal area, and 3) proportion of the stand in lodgepole pine (Steele and others 1996). Other pines can contribute to susceptibility of MPB within a stand in southern Idaho, but this model is limited to evaluating the lodgepole pine component only.

Although elevation has been used in many models as suggested by Amman and others (1977), more recent outbreaks in high-elevation lodgepole and other pine species in central Idaho have experienced high levels of mortality. This phenomenon has also been documented in Colorado (Tismsark 2007). Due to these observations, elevation was not used in this model.

Measurements

Inter-tree competition for nutrients, water, and light contribute to the stress of trees within a stand. Stand density is measured in square feet of basal area. Basal area of a stand with less than 80 square feet is considered to decrease susceptibility, but a stand with more than 120 square feet is considered to increase susceptibility. Stand densities of less than 60 square feet of basal area are generally considered too open to have inter-tree competition interactions on most sites.

Agent host preference for MPB is measured using the quadratic mean diameter (QMD) of lodgepole pine trees ≥ to 5 inches DBH. If the QMD of these host trees is less than 7 inches, the stand is rated least susceptible; but if it is greater than 8 inches it is rated most susceptible.

Mountain pine beetle seldom attacks trees with diameters smaller than 5 inches DBH. The proportion of host in square feet of basal area is computed for lodgepole pine ≥ 5 inches DBH. This is divided by the basal area of all trees > 0.1 inches DBH.

Computing the Susceptibility Result for Mountain Pine Beetle on Lodgepole Pine

Names of triggers and variables associated with the .kcp file calculations and output:

XMPB-LP	Susceptibility category result for MPB in lodgepole pine
_LPqmd2	QMD for lodgepole pine greater than or equal to 5 inch DBH
_LPProp2	Proportion of lodgepole pine greater than or equal to 5 inch DBH
_valba2	Rating value of total basal area (0.1, 1, 2, 3)
_valqmd2	Rating value of quadratic mean diameter (1, 2, 3)
_valSUS2	Rating result or product of the multiplicative formula

The stand susceptibility result is computed using the following multiplicative formula:

_valSUS2=*Inter-tree competition rating value* X *Agent host preference rating value* X *Quantity of suitable host proportion*

The stand susceptibility calculation will produce a result within a range of 0.01 to 9.00. The susceptibility result has a corresponding category value that is displayed in **XMPB-LP** column and is associated with a susceptibility category (Table 12).

Table 11. Stand susceptibility rating for mountain pine beetle in lodgepole pine.

Description of Measurement	**Measurement Attributes**	**Criteria and Associated Values**				**Rating**
		0.1	**1**	**2**	**3**	
Inter-tree Competition	Basal area of all tree species	< 60 sq. ft.	≥60 to <80 sq. ft.	≥80 to <120 sq. ft.	≥ 120 sq. ft.	Example Rating **BA=1**
Agent host preference	QMD of lodgepole pine ≥ 5 inches DBH		< 7 inches	≥7 to <8 inches	≥ 8 inches	Example Rating **QMD=3**
Quantity of suitable host available	Proportion of basal area that is lodgepole pine ≥5"DBH	0.01 to 1.00				Example Rating **Prop of BA=0.20**
Susceptibility Result Example Rating (1 x 3 x 0.20 =**0.6**) Then, from Table 8,Susceptibility. Category=**Low**						

Table 12. Susceptibility result, corresponding rating value and susceptibility category for the mountain pine beetle in lodgepole pine model.

Susceptibility Result _valsus2	**XMPB-LP Value**	**Susceptibility Category**
< 1.2	1	Low
1.2-1.99	1.5	Low-Moderate
2-2.99	2	Moderate
3-3.99	2.5	Moderate-High
≥4	3	High

References

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MOUNTAIN PINE BEETLE IN PONDEROSA PINE RATING

In southern Idaho, mountain pine beetle, (MPB), *Dendroctonus ponderosae* Hopkins, is not generally considered to be the primary bark beetle in ponderosa pine. *However, MPB can and does attack ponderosa pine stands that are adjacent to lodgepole pine stands.* Under those circumstances, this rating should be considered to rate the susceptibility of the ponderosa pine stands.

Susceptibility to MPB in ponderosa pine is similar to the susceptibility to MPB in lodgepole pine. The basic stand conditions for this rating are average diameter of the host species; density of the stand in square feet of basal area; and, proportion of ponderosa pine (Steele and others 1996). Groups of high density ponderosa pine trees with QMD greater than 6 inches DBH are susceptible (Olsen and others 1995). Although, all pines can contribute to susceptibility of MPB in a stand, this rating is limited to evaluating the ponderosa pine component. This rating method is very similar to Randall and Bush (2010).

Measurements

Inter-tree competition for nutrients, water, and light contribute to the stress of host trees. Density of the host in a stand is measured in square feet of basal area. Basal area of stands with less than 80 square feet per acre decreases susceptibility, but stands with more than 120 square feet per acre increases susceptibility. Total basal area of less than 60 square feet per acre is considered too low to support large populations of MPB. In addition, stand densities of less than 60 square feet of basal area per acre are generally considered too open to have inter-tree competition interactions on most sites.

Agent host preference is measured using the quadratic mean diameter (QMD) of ponderosa pine trees greater ≥ to 5 inch DBH. A 7 inch DBH is used for the low susceptibility threshold to reflect agent behavior in central Idaho. If the QMD of these host trees is less than 7 inches, susceptibility is decreased. But if it is greater than 10 inches susceptibility is increased.

Mountain pine beetle seldom attacks trees with diameters smaller than 5 inch DBH. The proportion of host in square feet of basal area is computed for ponderosa pine ≥ 5 inches DBH. This is divided by the basal area of all trees > 0.1 inches DBH.

Computing the Susceptibility Result for Mountain Pine Beetle in Ponderosa Pine

Names of triggers and variables associated with the .kcp file calculations and output:

XMPB-PP	Susceptibility category result for MPB in ponderosa pine
_PPqmd6	QMD for ponderosa pine ≥to 7 inch DBH
_PPProp6	Proportion of ponderosa pine ≥to 7 inch DBH
_valba6	Rating value of total basal area (0.1, 1, 2, 3)

The stand susceptibility result is computed using the following multiplicative formula:

_valSUS6 = *Inter-tree Competition rating value* X *Agent host Preference rating value* X *Quantity of host available proportion*

The stand susceptibility calculation will produce a result within a range of .01 to 9.0. The susceptibility result has a corresponding category value that is displayed in XMPB-PP column and is associated with a susceptibility category (Table 14).

Table 13.Rating for mountain pine beetle in ponderosa pine species.

Description of Measurement	Measurement Attributes	Criteria and Associated Values				Rating
		0.1	1	2	3	
Inter-tree Competition	Basal area of all tree species	< 60 sq. ft.	≥60 to <80 sq. ft.	≥80 to <120 sq. ft.	≥ 120 sq. ft.	Example Rating **BA=2**
Agent host preference	QMD of ponderosa pine ≥ 5 inches DBH		< 7 inches	≥7 to <10 inches	≥ 10 inches	Example Rating **QMD=1**
Quantity of suitable host available	Proportion of ponderosa pine basal area that is ≥5"DBH	0.01 to 1.00				Example Rating **Prop of BA=0.33**
Susceptibility Result Example Rating (2 x 1 x 0.33 =**0.66**) Then, from Table 14, Susceptibility Category=**Low**						

Table 14. Susceptibility result, corresponding model value and susceptibility category for the mountain pine beetle in ponderosa pine rating.

Susceptibility Result _valsus2	XMPB-PP Value	Susceptibility Category
< 1.2	1	Low
1.2-1.99	1.5	Low-Moderate
2-2.99	2	Moderate
3-3.99	2.5	Moderate-High
≥4	3	High

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MOUNTAIN PINE BEETLE IN WHITEBARK/LIMBER PINE RATING

The high elevation five-needle pines, as a group, provide essential habitat for wildlife, often being the major source of cover in high elevation environments. The range of limber pine partially overlaps with that of whitebark pine. Both species have large, bird-dispersed seeds, and both are highly susceptible to white pine blister rust, an exotic fungus. The two species are so similar in appearance it is only possible to distinguish between them when cones are present. Most recent work on MPB in high elevation pines has been centered on whitebark pine; however, much of the information appears to apply to limber pine as well.

Stand Conditions Conducive to Infestations

Historically the principal mortality agent of whitebark pine was the MPB. Perkins and Roberts (2003) found tree and stand-level characteristics associated with MPB attack in whitebark pine are qualitatively similar to other MPB-pine host systems, although the attack thresholds are quantitatively different. Whitebark pine stands with basal areas below 44 square feet per acre and trees with average DBH below 7 inches were not readily attacked during the 1930s MPB outbreak in central Idaho. These factors and authors experience were used to build the whitebark/limber pine hazard criteria for this MPB model.

Computing the Susceptibility Result for Mountain Pine Beetle on Whitebark or Limber Pine

Names of triggers and variables associated with the .kcp file calculations and output:

WBBt	Susceptibility category result for MPB in whitebark/limber pine
_valqmd14	QMD for pine host ≥ l to 5 inch DBH
_WBBProp14	Proportion of pine ≥ to 5 inch DBH
_valba14	Rating value of total basal area (0.1, 1, 2, 3)

The stand susceptibility result is computed using the following multiplicative formula:

_valSUS2=*Inter-tree competition rating value* X *Agent host preference rating value* X *Quantity of suitable host proportion*

The stand susceptibility calculation will produce a result within a range of 0.01 to 9.00. The susceptibility result has a corresponding category value that is displayed in WBBtl column and is associated with a susceptibility category (Table 15). See Appendix A for the list of variable names in the .kcp file and output.

Interpreting Hazard

Hazard is defined by two factors—the quality and the quantity of susceptible whitebark (WB) and limber pine (LM). The quality of the pine component of a stand as a MPB food source is best characterized by stand density and phloem thickness. Since phloem thickness is not generally measured in inventories, DBH and other available stand characteristics are used as surrogates. The quantity of the food source refers to the species composition and density of the forest. A pure, well stocked pine stand will be more likely to support a large MPB population than a mixed species and/or poorly stocked stand.

When high-hazard stands are intermixed with low-hazard stands, beetle populations may not be as active. Low-hazard stands may have WB and LM, but are either not of high enough quality or in large enough quantity to allow beetle populations to remain at high levels. Mountain pine beetle may still cause significant mortality in the WB and LM components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazards are clustered.

Table 15. Rating for mountain pine beetle in whitebark pine/limber pine

Description of Measurement	Measurement Attributes	Criteria and Associated Values				Rating
		0.1	1	2	3	
Inter-tree Competition	Basal area of all tree species	< 25 sq. ft.	25-45	45-60	≥ 60 sq. ft.	Example Rating **BA=0.1**
Agent host preference	QMD of whitebark and limber pine ≥ 5 inches DBH		< 7 inches	Range between low and high	≥ 10 inches	Example Rating **QMD=3**
Quantity of suitable host available	Proportion of basal area that is ≥5"DBH + Limber 5"DBH + whitebark ≥ 5" DBH +lodgepole ≥ 5" DBH + ponderosa pine ≥ 5" DBH	0.01 to 1.00				Example Rating **Prop of BA=0.45**
Susceptibility Result Example Rating (.1 x 3 x 0.45 =**1.35**) Then, from Table 16, Susceptibility Category=**Low-Moderate**						

Table 16. Susceptibility result, corresponding rating value and susceptibility category for the mountain pine beetle in whitebark/limber pine rating.

Susceptibility Result _valsus2	XMPB-LP Value	Susceptibility Category
< 1.2	1	Low
1.2-1.99	1.5	Low-Moderate
2-2.99	2	Moderate
3-3.99	2.5	Moderate-High
>=4	3	High

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COMBINED BARK BEETLES FOR PINE HOSTS

A number of bark beetles, including MPB, pine engraver beetles (Ips species), and WPB, attack and kill pine (*Pinus*) species. Hazard rating systems have been developed for individual host

species; however, these systems may not accurately assess the hazard of stands containing multiple pine species. It may be necessary to group pine species components in order to assess hazard for project objectives.

We developed this hazard rating system by integrating the individual host species hazard rating systems presented in this document. This rating is appropriate for larger scale planning efforts. Use the individual species ratings for more refined analysis and contact FHP if you have questions.

Stand Conditions Conducive to Infestations
Susceptible mixed pine stands are dense and have a large combined pine species component of trees > 5 inches DBH.

Computing the Susceptibility Result for Bark Beetles in Pine

Names of triggers and variables associated with the .kcp file calculations and output:

CBtl	Susceptibility category result for combined species of pine
_ProppBA	Proportion of pine ≥ to 6 inches
_BWBAHST	Total basal area of host for pine beetles, includes ponderosa, lodgepole, whitebark and limber pine.

The stand susceptibility result is computed using the following multiplicative formula:

_valSUS2=*Inter-tree competition rating value* X *Agent host preference rating value* X *Quantity of suitable host proportion*

The stand susceptibility calculation will produce a result within a range of 0.01 to 9.00. The susceptibility result has a corresponding category value that is displayed in CBtl column and is associated with a susceptibility category (Table 18).

Table 17. Stand susceptibility criteria for bark beetles in several pine hosts.

Description of Measurement	Measurement Attributes	Criteria and Associated Values				Rating
		0.1	1	2	3	
Inter-tree Competition	Basal area of all tree species	< 60 sq. ft.	≥60 to <80 sq. ft.	≥80 to <120 sq. ft.	≥ 120 sq. ft.	Example Rating **BA=1**
Agent host preference	QMD of pine ≥ 5 inches DBH		< 6 inches	≥6 to <8 inches	≥ 8 inches	Example Rating **QMD=3**
Quantity of suitable host available	Proportion of basal area that is ≥5"DBH + Limber 5"DBH + whitebark ≥ 5" DBH +lodgepole ≥ 5" DBH + ponderosa pine ≥ 5" DBH	0.01 to 1.00				Example Rating **Prop of BA=0.20**
Susceptibility Result Example Rating (1 x 3 x 0.20 =**0.6**) Then, from Table 18, Susceptibility Category=**Low**						

Table 18.-Susceptibility result, corresponding rating value and susceptibility category for the pine beetles in a combined host rating.

Susceptibility Result	CBB-TL Value	Susceptibility Category
< 1.2	1	Low
1.2-1.99	1.5	Low-Moderate
2-2.99	2	Moderate
3-3.99	2.5	Moderate-High
>=4	3	High

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SPRUCE BEETLE RATING

Spruce beetle (*Dendroctonus rufipennis* (Kirby)) outbreaks cause extensive tree mortality and modify stand structure by reducing the average spruce tree diameter, height, and stand density. Residual trees are often slow-growing small and intermediate-sized trees which eventually become dominant. In the Rocky Mountain West, Engelmann spruce is the species most often impacted.

Spruce Conditions conducive to Infestations:
Endemic spruce beetle populations usually live in windthrown trees. When populations increase to high levels in in downed trees, beetles may attack susceptible large-diameter standing trees. Most outbreaks originate in wind-thrown trees. Once beetle populations reach high levels, more relatively healthy trees are attacked.

In mature stands, larger diameter (18 inches DBH or bigger) trees are attacked first. If an infestation persists in a stand, smaller diameter trees may be attacked.

Engelmann spruce stands are highly susceptible if they grow on well-drained sites in creek bottoms, have an average DBH of 16 inches or more, have a basal area > 150 square feet per acre, and have more than 65 percent spruce in the canopy.

Highly susceptible stands are those in which large amounts of spruce mortality can be expected once a landscape level spruce beetle outbreak occurs. Moderate stands may experience less beetle-caused mortality during such an outbreak, but many individual large, old spruce trees will likely be killed. In a landscape where highly and moderately susceptible stands are clustered around a few low susceptible stands, spruce beetle may cause significant mortality of the spruce component in the low susceptible stands as well. On the contrary, when a few highly susceptible stands are intermixed with low and moderate susceptible stands, beetle populations may not be as active. Low susceptible stands may have spruce, but are either not of high enough quality or in large enough quantity to maintain high beetle populations at the landscape level.

Computing the Susceptibility Result for Spruce Beetle in Engelmann Spruce

Names of triggers and variables associated with the .kcp file calculations and output:

XSBES	Susceptibility category result for spruce beetle
_valqmd10	QMD for Engelmann spruce ≥10 inch DBH
_ESProp10	Proportion of Engelmann spruce ≥5 inch DBH
_valba10	Rating value of total basal area (0.1, 1, 2, 3)

The stand susceptibility result is computed using the following multiplicative formula:

_valSUS2=*Inter-tree competition rating value* X *Agent host preference rating value* X *Quantity of suitable host proportion*

The stand susceptibility calculation will produce a result within a range of 0.01 to 9.00. The susceptibility result has a corresponding category value that is displayed in WBBtl column and is associated with a susceptibility category (Table 20).

Table 19. Stand susceptibility criteria for spruce beetles in Engelmann spruce.

Description of Measurement	Measurement Attributes	Criteria and Associated Values				Rating
		0.1	1	2	3	
Inter-tree Competition	Basal area of all tree species	< 60 sq. ft.	≥60 to <100 sq. ft.	≥100 to <150 sq. ft.	≥ 150sq. ft.	Example Rating **BA=1**
Agent host preference	QMD of spruce ≥ 10 inches DBH		< 12 inches	≥12 to <16 inches	≥ 16 inches	Example Rating **QMD=3**
Quantity of suitable host available	Proportion of basal area that of spruce ≥10"DBH	0.01 to 1.00				Example Rating **Prop of BA=0.20**
Susceptibility Result Example Rating (1 x 3 x 0.20 =**0.6**) Then, from Table 20, Susceptibility Category=**Low**						

Table 20. Susceptibility result, corresponding rating value and susceptibility category for spruce beetle.

Susceptibility Result	CBB-TL Value	Susceptibility Category
< 1.2	1	Low
1.2-1.99	1.5	Low-Moderate
2-2.99	2	Moderate
3-3.99	2.5	Moderate-High
>=4	3	High

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WESTERN SPRUCE BUDWORM AND/OR DOUGLAS-FIR TUSSOCK MOTH IN DOUGLAS-FIR, SUBALPINE FIR, GRAND FIR, ENGELMANN SPRUCE RATING

Western spruce budworm (*Choristoneura freemani*) and Douglas-fir tussock moth (*Orgyia pseudotsugata)* are native, defoliating insects which eat the needles of Douglas-fir, Engelmann spruce, subalpine fir, and grand fir in central Idaho forests. Although larch and some pines are incidental hosts, these species will not be included for this stand susceptibility model. These defoliators rarely completely defoliate large trees but growth-loss, top kill, and occasional mortality can occur after several years of defoliation (Beveridge and Cahill 1984, Fellin and Dewey 1982). When populations of these insects reach epidemic proportions, they can cause a reduction in growth, top kill, tree mortality, and mortality of regenerating trees. Western spruce budworm outbreaks tend to last longer and cause less direct tree mortality because budworms preferentially feed on current year foliage. Whereas, Douglas-fir tussock moth outbreaks tend to be shorter in duration (2-3 years), but result in more mortality loss because tussock moth larvae often completely defoliate a tree. Larvae of both species will defoliate any size class but mortality occurs mostly in smaller, suppressed trees after consecutive years of defoliation, or trees with over 90 percent defoliation in one year (Brookes et al. 1978, Weatherby et al. 1992). Impacts from defoliation can contribute to stress in the stand often making trees more susceptible to other agents such as bark beetles.

Stand Conditions Conducive to Infestation

Because larvae of both species disperse by moving up and out from their egg masses and spinning silken thread to "balloon" on the wind to a new host, they tend to be more destructive in dense (high basal area) stands with a high host (Douglas-fir/true fir) component and multiple canopy layers which intercept ballooning larvae (Randall and Bush 2010). Typically, drier sites exhibit more defoliation. Therefore, species composition, stand density, and stand structure, and site moisture are common measures of susceptibility (Wulf and Cates 1985). Because susceptible hosts in southern Idaho include Douglas-fir, Engelmann spruce, subalpine fir, and grand fir, all measurements used in the rating will be additive for these host trees. The proportion of host in square feet of basal area is computed for all host trees ≥ 5 inches DBH and added together. This is then divided by the basal area of all trees > 0.1 inches DBH. To estimate stand structure, this model considers both the presence of basal area of 5 inch and larger DBH trees as the "quantity of hosts in the stand", and canopy cover of host trees less than 8 inches DBH as the "quantity of hosts not in the overstory." Lastly, to represent site moisture, habitat types of central Idaho are broken out into moisture categories (Geier-Hayes personal communication 2014, Steele et al. 1981).

Computing the Susceptibility Result for Western Spruce Budworm

Names of triggers and variables associated with the .kcp file calculations and output:

XBw	Susceptibility category result for western spruce budworm
_BWProp5	Proportion of basal area of host for western spruce budworm. Includes Douglas-fir, subalpine fir, grand fir, and Engelmann spruce
_BwCCsm5	Percent canopy cover of trees < 8 inch DBH
_valBa5	Rating value of total basal area (1, 2, 3)
_habmoist	Rating value for moisture (1, 2, 3)
_valPro5	Rating value for the proportion of host (1, 2, 3)
_valccS5	Rating value for the percent canopy cover (1, 2)
_valAll5	Rating result or product of the multiplicative formula

The stand susceptibility result is computed using the following multiplicative formula:

_valAll5 = *Inter-tree Competition rating value* X *Quantity of overstory hosts rating value* X *small tree canopy cover rating value*

The stand susceptibility calculation will produce a result within a range of 1 to 18. The susceptibility result has a corresponding category value that is displayed in XBw column and is associated with a susceptibility category (Table 22).

A susceptibility category of high indicates that these stands could support outbreak population levels; and, it follows that the associated risk of overstory mortality from defoliation-alone during an outbreak is greatest for these stands.

Table 21. Rating criteria for western spruce budworm and Douglas-fir tussock moth where each measurement attribute gets assigned a rating of 1, 2, or 3 depending on the value for the stand.

Description of Measurement	**Measurement Attributes**	**Criteria and Associated Rating Values**			**Rating**
		1	**2**	**3**	
Inter-Tree Competition	Basal area of all tree species per acre	< 100 sq ft.	≥100 to <180 sq. ft.	≥ 180 sq. ft.	Example **1**
Quantity of hosts available in the Stand	Proportion of total basal area of host trees > 5 inches DBH	< .40	≥0.40 to <0.80 sq. ft.	≥ .80	Example **2**
Agent dispersal, survival: Quantity of hosts not in the overstory	Stand structure measuring canopy cover for host trees less than 8 inch diameter	< 25 %	≥ 25 %		Example **1**
Site Moisture	Habitat Type	50-195, 210-265, 310-398, 505, 585, 705, 732, 745-791, 905-955	250, 280, 390,393, 440, 510-580, 640, 645, 690-692, 720-734, 810	290, 410, 490-493, 520, 590-593, 605, 620-625, 635-638, 650-655, 660-663, 670-672, 694, 740, 830, 833	Example **1**
Susceptibility Result Example(1 x 2 x 1 x1)=2 Then, using Table 22 below**, susceptibility category = Low**					

Table 22. Converting the susceptibility result from the Table 19 rating criteria into a susceptibility category of low, moderate or high.

Susceptibility Result _valAll5	**XBw Value**	**Susceptibility Category**
< 4	1	Low
4-27	2	Moderate
≥27	3	High

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DWARF MISTLETOE IN DOUGLAS-FIR, LODGEPOLE PINE, PONDEROSA PINE, AND WESTERN LARCH

Dwarf Mistletoe *(Arceuthobium spp*.) is a native parasitic plant that reduces tree vigor, growth, and can cause mortality in all age classes. It can increase a tree's susceptibility to other disturbances such as bark beetles and fire as well. There are thirty-nine taxa of *Arceuthobium* in North America; only 10 dwarf mistletoe taxa have one specific tree species as principle host (Hawksworth and Wiens 1996). Of the four dwarf mistletoes listed in the title of this chapter, Douglas-fir dwarf mistletoe is the only dwarf mistletoe species with one principal host (Hadfield et al. 2000, Hawksworth and Wiens 1996). Trees are infected when dwarf mistletoe seeds are projected from the parent plant. These projections are dependent upon quantity and position of adjacent host (Schwandt 1977). Projections often go outward and downward impacting the lower levels of the stand structure. Stands of more pure host are more susceptible than stands mixed with other non-host trees species. Unlike insects, the seed source cannot seek out its host but relies on parent plant presence and host adjacent or beneath plant location. Therefore mistletoe presence is used in this rating.

A standard measure of mistletoe presence and intensity is the 6-class dwarf mistletoe rating (DMR) system introduced by Hawksworth and Lusher (1956). Hawksworth (1961) described the six-class dwarf mistletoe system in more detail. For this method, the live crown is visually divided into thirds (Figure 4). An infection rating from 0 to 2 is assigned to each crown third. The result of each crown third is added to compute the final intensity rating. Infection rates are important as a rating of 6 indicates that the infection is distributed among all three levels of the crown and increases significantly the ability of mistletoe to spread to other trees around it and below it. Whereas a rating of 1 indicates the infection is located in one of the thirds of the crown and more limited in its dispersal.

Using the Hawksworth system, the model simulates dwarf mistletoe infection levels in three parts of each tree: upper, middle, and lower thirds of the live crown. Infestation is classified by assigning each crown third a 0-2 rating.

For stand exams or forest inventory exams, mistletoe intensity is recorded in the field during a survey and completed for each tree that has mistletoe infection. The information is provided to FVS in the form of damage and severity codes in the input tree records. When FVS processes the input tree data, the DMR values are used to initialize the Dwarf Mistletoe Impact Model (updated David 2005). The Dwarf Mistletoe Impact Model simulates the spread and intensification of dwarf mistletoe throughout a stand, and estimates the effects of dwarf mistletoe on tree and stand development. A variety of summaries are included in the FVS output file that reports spread, intensification and mortality by host species. A dwarf mistletoe rating is computed for all trees (infected and non-infected) in each host type and is projected for each cycle of the simulation. These dwarf mistletoe ratings (DMR) by host type will be used as a measurement of susceptibility. For more information about the Dwarf Mistletoe Impact Model and the output summaries, see "Dwarf Mistletoe Impact Modeling System, Users Guide and Reference Manual, Nonspatial model, 2005 update" by Lance R David, unpublished report by the USDA Forest Service, Forest Health Technology Enterprise Team.

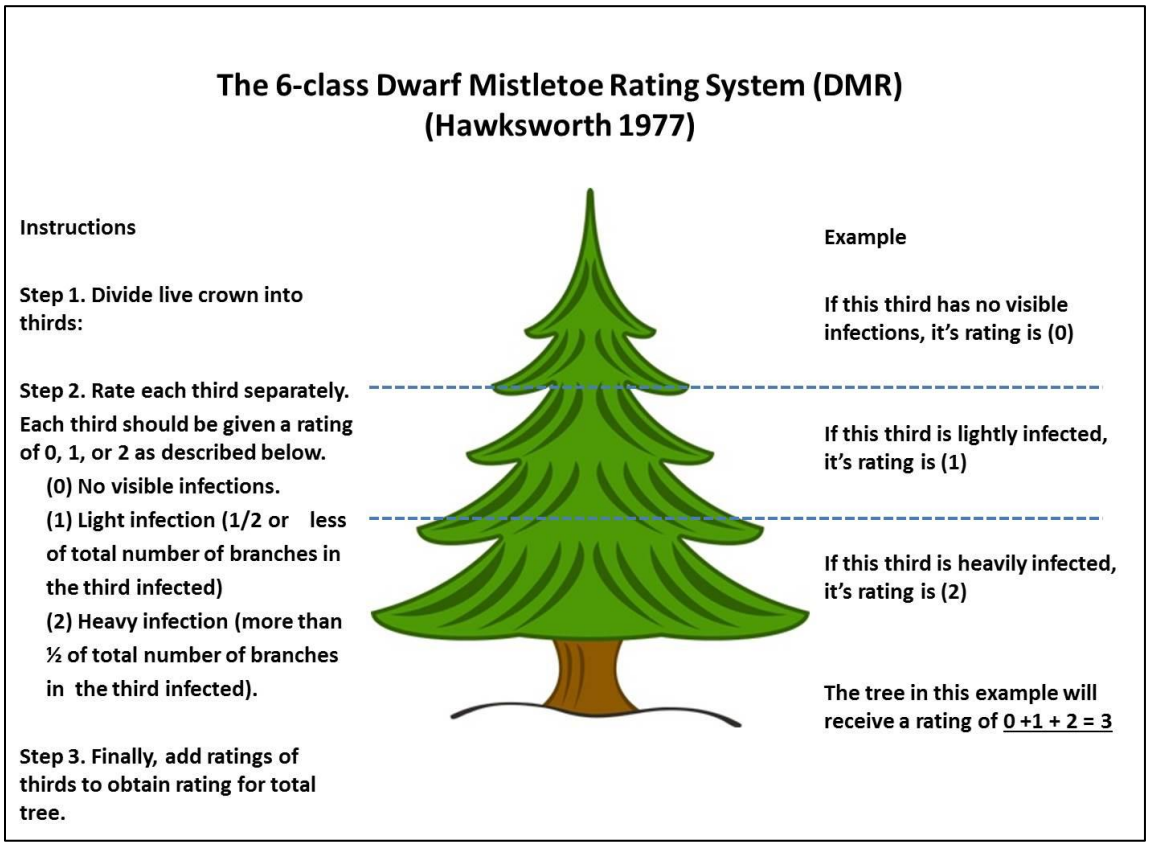

Figure 4. Dwarf Mistletoe rating system (DMR) Graphic depicting the visual 6-class dwarf mistletoe rating system introduced by Hawksworth (1961, 1977).

Computing the Susceptibility Result for Dwarf Mistletoe

Names of triggers and variables associated with the .kcp file calculations and output:

_DFDMR	Stores the value of the average dwarf mistletoe rating in Douglas-fir trees.
XDFMst	Rating result for Douglas-fir.
_PPDMR	Stores the value of the average dwarf mistletoe rating in ponderosa pine trees.
XPPMst	Rating result for ponderosa pine.
_LPDMR	Stores the value of the average dwarf mistletoe rating in lodgepole pine trees.
XLPMst	Rating result lodge pole.
_WLDMR	Stores the value of the average dwarf mistletoe rating in western larch trees.
XWLMst	Rating result western larch.

The rating values of 1, 2 or 3 are categorized for each host species DMR and used in the following dwarf mistletoe susceptibility outputs in FVS: XPPMst, XLPMst, XDFMst, XWLMst.

Table 23. Dwarf mistletoe categories.

Stand Dwarf Mistletoe Rating for each tree species	Model Value Category XPPMst XLPMst XDFMst XWLMst	Susceptibility Category
< 1	1	Low
1-3	2	Moderate
>3	3	High

References

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APPENDIX A – INSECT HAZARD RATING.KCP

```
********************************************************************************
* R4-SSRS-FVS_CI_v2.kcp -- Forest Health Hazard Rating            (3/05/2015)  *
* Stand Susceptability Rating System (SSRS)                                   *
* Central Idaho Variant                                                       *
*                                                                             *
* Laura Lowrey 208-373-4226 (FHP), Carl Jorgensen 208-373-4225 (FHP),         *
* Lance David (FMSC)970-295-5856                                              *
*                                                                             *
* A conditional is used to trigger each rating system if host is present.     *
*                                                                             *
*  -------------------------                                                  *
*                                                                             *
*  Douglas-fir Beetle: XDFBtl                                                 *
*                       Very low  Low    Moderate   High      Multiplicative  *
*  QMD DF >= 9" DBH               <10                >=14     L    <1.2       *
*                                                             L-M   1.2-2     *
*  Stand Basal Area      <60      <120               >=220    M     2.0-3.0   *
*  Multipled by % BA of host >= 9 inches                      M-H   3-4.0     *
*                                                             H     >=4.0     *
*---------------------------                                                  *
*  Ponderosa Pine -Mixed Conifer(Western Pine Beetle): XWPBt-M                *
*   Ponderosa pine BA must be <= 80 percent to trigger this model             *
*                       Very low  Low   Moderate   High      Multiplicative  *
*  QMD PP >= 5" DBH               <12               >=20     L    <1.2       *
*  Stand Basal Area         <60    <80               >=120    L-M   1.2-2     *
*  Multipled by % BA of host >= 5 inches             <=80     M     2.0-3.0   *
*                                                             M-H   3-4.0     *
*                                                             H     >=4.0     *
*  -------------------------                                                  *
*  Ponderosa Pine 2nd growth (Western Pine Beetle) XWPBt-P2                   *
*  Ponderosa pine BA must be > 80 percent to trigger this model               *
*                       Very low  Low   Moderate   High     Multiplicative   *
*  QMD PP >= 5" DBH               <8                >=12    L    <1.2        *
*  Stand Basal Area         <60   <80                >=120   L-M   1.2-2      *
*   Multipled by % BA of host >= 5 inches            > 80    M     2.0-3.0    *
*                                                             M-H   3-4.0     *
*                                                             H     >=4.0     *
*  -------------------------                                                  *
*  Ponderosa Pine  (Mountain Pine Beetle): XMPB-PP                            *
*   Ponderosa pine                                                            *
*                       Very low  Low    Moderate   High     Multiplicative   *
*  QMD PP >= 5" DBH               <7                >=10    L    <1.2        *
*  Stand Basal Area         <60   <80                >=120   L-M   1.2-2      *
*  Multipled by % BA of host >= 5 inches                     M     2.0-3.0    *
*                                                             M-H   3-4.0     *
*                                                             H     >=4.0     *
*  -------------------------                                                  *
*  Lodgepole Pine (Mountain Pine beetle):  XMPB-LP                            *
*                       Very low  Low    Moderate   High     Multiplicative   *
*  QMD LP >= 5" DBH               <7                >=8     L    <1.2        *
*  Stand Basal Area        <40    <80                >=120   L-M   1.2-2      *
*  Multipled by % BA of host >= 5 inches                     M     2.0-3.0    *
*                                                             M-H   3-4.0     *
*                                                             H     >=4.0     *
*  -------------------------                                                  *
*  Western Spruce Budworm/Douglas-fir Tussock Moth: XBw                       *
*                            Low    Moderate     High       Multiplicative   *
*  Stand Basal Area          <100                >=180        L=   <4         *
*  % BA: ES, AF, GF, DF      <40                 >=80         M=  4-27        *
*       >= 5" DBH                                            H=   >=27       *
*  % Canopy Cover < 5" DBH   <5 %                >=  5 %                      *
*       trees                                                                 *
*  Habitat Type                                                               *
*  -------------------------                                                  *
*  Separate Mistletoe models in Ponderosa pine, Lodgepole pine, Western larch *
*  or Douglas-fir.                                                            *
*                           Low     Moderate     High                         *
```

```
*  Average Dwarf Mistletoe                                                    *
*  Rating for each host       <1                  > 3                         *
*    DMR for PP,LP,WL,                                                        *
*    or DF from Event monitor                                                 *
*                PP=XPPMst ,LP=XLPMst, WL=XWLMst,or DF=XDFMst                 *
*   -------------------------                                                 *
*   Whitebark pine/Limber Pine (MPB): WBBtl                                   *
*                                                                             *
*                        Very low  Low    Moderate   High     Multiplicative  *
*  QMD LP >= 5" DBH                <7                >=8      L    <1.2       *
*  Stand Basal Area        <40     <80                >=120    L-M   1.2-2     *
*  Multipled by % BA of host >= 5 inches                       M     2.0-3.0   *
*                                                              M-H   3-4.0     *
*                                                              H     >=4.0     *
*   -------------------------                                                 *
*   Spruce Beetle: XSBES                                                      *
*                     Very low   Low    Moderate   High      Multiplicative   *
*   QMD ES >= 10" DBH            <10                >=14     L      <1.2       *
*                                                             L-M   1.2-2      *
*   Stand Basal Area      <60   <120                >=220    M   2.0-3.0      *
*   Multipled by % BA of host >= 10 inches                    M-H   3-4.0      *
*                                                             H     >=4.0      *
*                                                                             *
*   -------------------------                                                 *
*   Combined Host (MBP):  XCBBtl                                              *
*                       Very low  Low    Moderate   High     Multiplicative   *
*   QMD LP >= 5" DBH                <7                >=8       L    <1.2      *
*   Stand Basal Area        <40     <80                >=120     L-M   1.2-2    *
*   Multipled by % BA of host >= 5 inches                        M     2.0-3.0  *
*                                                                M-H   3-4.0    *
*                                                                H     >=4.0    *
*                                                                             *
* =========================================================================== *
*  Hazard Ratings Values:                                                     *
*        0   - No Host                                                        *
*                1   - Low                                                    *
*                1.5 - Low-Moderate                                           *
*                2   - Moderate                                               *
*                2.5 - Moderate-High                                          *
*                3   - High                                                   *
*****************************************************************************
* Budworm hosts are:
* white fir, grand fir, subalpine fir, Engelmann spruce and Douglas-fir
* Define species group of budworm host - CI variant
SpGroup         BWSP
DF ES AF

* variables common to more than one model or used as triggers for condition
Compute            0
*Trigger for spruce beetle in ES and ComboMax (MPB)
_ProESBA = SpMcDBH(2,ES,0,5,999,0,999,0)/ (SpMcDBH(2,All,0,.1,999,0,999,0) +.00001)
*Trigger to determine which western pine beetle rating in ponderosa pine
_ProPPBA = SpMcDBH(2,PP,0,5,999,0,999,0)/ (SpMcDBH(2,All,0,.1,999,0,999,0) +.00001)
*Trigger the western spruce budworm model
_BWBAHst = SpMcDBH(2,BWSP,0,.1,999,0,999,0)
*Basal area of the stand, used in most ratings is EM variable BBA.
End

*****************************************************************************
*XDFBtl = Douglas-fir Beetle in Douglas-fir

If                 0
SpMcDBH(2,DF,0,9,999,0,999,0) GT .1
Then
Compute            0

*average diameter of the host >= 9 inches
_dfqmd1 = SpMcDBH(5,DF,0,9,999,0,999,0)
```

```
*Proportion of host >= 9 inches
_DFProp1 = SpMcDBH(2,DF,0,9,999,0,999,0) / Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)

*values for susceptibility
_vba1 = LinInt(BBA,0,60,60,120,120,220,220,999,.1,.1,1,1,2,2,3,3)
_vqmd1 = LinInt(_dfqmd1,0,10,10,14,14,999,1,1,2,2,3,3)
_vSUS1 =  _vqmd1 * _vba1 * _DFProp1
XDFBtl = LinInt(_vSUS1,0,1.2,1.2,2,2,3,3,4,4,999,1,1,1.5,1.5,2,2,2.5,2.5,3,3)

End
Endif

*************************************************************************
*XWPBtP2 = Western Pine Beetle in Ponderosa Pine - 2nd growth > 80 % PP
If               0
_ProPPBA GT .80 And SpMcDBH(2,PP,0,5,999,0,999,0) GT .1
Then
Compute          0

*average diameter of the host >= 5 inches
_PPqmd3 = SpMcDBH(5,PP,0,5,999,0,999,0)

*Proportion of host >= 5 inches
_PPProp3 = SpMcDBH(2,PP,0,5,999,0,999,0) /Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)

*values for susceptibility
_vba3 = LinInt(BBA,0,60,60,80,80,120,120,999,.1,.1,1,1,2,2,3,3)
_vqmd3 = LinInt(_PPqmd3,0,8,8,12,12,999,1,1,2,2,3,3)
_vSUS3 =  _vqmd3 * _vba3 * _PPProp3
XWPBtP2 = LinInt(_vSUS3,0,1.2,1.2,2,2,3,3,4,4,999,1,1,1.5,1.5,2,2,2.5,2.5,3,3)

End
Endif

*************************************************************************
*XWPBtM = Ponderosa Pine (WPB) Mixed conifer <= 80 % PP
If               0
_ProPPBA LE .80 And _ProPPBA GT .01  And SpMcDBH(2,PP,0,5,999,0,999,0) GT .1
Then
Compute          0
*average diameter of the host >= 5 inches
_PPqmd4 = SpMcDBH(5,PP,0,5,999,0,999,0)


*Proportion of host >= 5 inches
_PPProp4 = SpMcDBH(2,PP,0,5,999,0,999,0) / Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)

*values for susceptibility
_vba4 = LinInt(BBA,0,60,60,80,80,120,120,999,.1,.1,1,1,2,2,3,3)
_vqmd4 = LinInt(_PPqmd4,0,12,12,20,20,999,1,1,2,2,3,3)
_vSUS4 =  _vqmd4 * _vba4 * _PPProp4
XWPBtM =LinInt(_vSUS4,0,1.2,1.2,2,2,3,3,4,4,999,1,1,1.5,1.5,2,2,2.5,2.5,3,3)

End
Endif

*************************************************************************
*XMPBPP =  Mountain Pine Beetle in Ponderosa Pine
If               0
_ProPPBA GT .01
Then
Compute          0
*average diameter of the host >= 5 inches
_PPqmd6 = SpMcDBH(5,PP,0,5,999,0,999,0)


*Proportion of host >= 5 inches
_PPProp6 = SpMcDBH(2,PP,0,5,999,0,999,0) / Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)
```

```
*values for susceptibility
_vba6 = LinInt(BBA,0,60,60,80,80,120,120,999,.1,.1,1,1,2,2,3,3)
_vqmd6 = LinInt(_PPqmd6,0,7,7,10,10,999,1,1,2,2,3,3)
_vSUS6 =  _vqmd6 * _vba6 * _PPProp6
XMPBPP =LinInt(_vSUS6,0,1.2,1.2,2,2,3,3,4,4,999,1,1,1.5,1.5,2,2,2.5,2.5,3,3)

End
Endif
*******************************************************************************
*XMPBLP = Mountain pine Beetle in Lodgepole Pine
If                0
SpMcDBH(2,LP,0,5,999,0,999,0) GT .1
Then
Compute           0
*average diameter of the host >= 5 inches
_LPqmd2 = SpMcDBH(5,LP,0,5,999,0,999,0)


*Proportion of host >= 5 inches
_LPProp2 = SpMcDBH(2,LP,0,5,999,0,999,0) / Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)

*values for susceptibility
_vba2 = LinInt(BBA,0,40,40,80,80,120,120,999,.1,.1,1,1,2,2,3,3)
_vqmd2 = LinInt(_LPqmd2,0,7,7,8,8,999,1,1,2,2,3,3)
_vSUS2 = _vqmd2 * _vba2 * _LPProp2
XMPBLP  = LinInt(_vSUS2,0,1.2,1.2,2,2,3,3,4,4,999,1,1,1.5,1.5,2,2,2.5,2.5,3,3)

End
Endif

*******************************************************************************
*XBw =W Spruce Budworm/Douglas-fir Tussock Moth

If                0
_BWBAHst gt .1
Then
**** Moisture assignment Dry (3), Mod (2), Moist (1)
**** HabType codes split into two groups to assign moisture code
**** CI variant
COMPUTE            0
_MOIS1 = LININT(HABTYPE, &
 250, 250, 260, 260, 280, 280, 290, 290, 310, 310, 390, 390, 392, 392, &
 393, 393, 395, 395, 410, 410, 440, 440, 490, 490, 500, 500, 510, 510, &
 520, 520, 525, 525, 585, 585, &
   3,   2,   2,   3,   3,   2,   2,   1,   1,   3,   3,   2,   2,   3, &
   3,   2,   2,   3,   3,   1,   1,   2,   2,   1,   1,   3,   3,   2, &
   2,   1,   1,   2,   2,  -1)

_MOIS2 = LININT(HABTYPE, &
 590, 590, 640, 640, 650, 650, 690, 690, 694, 694, 700, 700, 720, 720, &
 740, 740, 745, 745, 810, 810, 830, 830, 850, 850, &
  -1,   1,   1,   2,   2,   1,   1,   2,   2,   1,   1,   3,   3,   2, &
   2,   1,   1,   3,   3,   2,   2,   1,   1,   3)

_HABMOIS = MAX(_MOIS1, _MOIS2)

END

Compute           0

*Proportion of BA host species group
_BWProp5 = SpMcDBH(2,BWSP,0,.1,999,0,999,0) / &
           Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)

*Canopy cover in less than 8 inch host trees
_BwCCsm5 = SpMcDBH(7,BWSP,0,.1,8,0,999,0)
_vBa5 = LinInt(BBA,0,100,100,180,180,999,1,1,2,2,3,3)
_vPro5 = LinInt((_BWProp5*100),0,40,40,80,80,999,1,1,2,2,3,3)
_vccS5 = LinInt(_BwCCsm5,0,25,25,999,1,1,2,2)
```

```
_vAll5 = _vBa5 * _vPro5 * _vccS5

XBw = LinInt((_vAll5 * _HABMOIS),0,4,4,27,27,999,1,1,2,2,3,3)

End
Endif

*********************************************************************************
*XDFMst=Douglas-fir Mistletoe,
If                0
SpMcDBH(8,DF,0,0,999,0,999,0) Gt 0
Then
Compute           0

_DFDMR = SpMcDBH(8,DF,0,0,999,0,999,0)
XDFMst = LinInt(_DFDMR,0,1,1,3,3,999,1,1,2,2,3,3)

End
Endif

*XPPMst=Ponderosa pine Mistletoe,
If                0
SpMcDBH(8,PP,0,0,999,0,999,0) GT 0
Then
Compute           0

_PPDMR = SpMcDBH(8,PP,0,0,999,0,999,0)
XPPMst = LinInt(_PPDMR,0,1,1,3,3,999,1,1,2,2,3,3)

End
Endif

*XLPMst= Lodgepole pine Mistletoe,
If                0
SpMcDBH(8,LP,0,0,999,0,999,0) GT 0
Then
Compute           0

_LPDMR = SpMcDBH(8,LP,0,0,999,0,999,0)
XLPMst = LinInt(_LPDMR,0,1,1,3,3,999,1,1,2,2,3,3)

End
Endif

*XWLMst=Western Larch Mistletoe,
If                0
SpMcDBH(8,WL,0,0,999,0,999,0) GT 0
Then
Compute           0

_WLDMR = SpMcDBH(8,WL,0,0,999,0,999,0)
XWLMst = LinInt(_WLDMR,0,1,1,3,3,999,1,1,2,2,3,3)

End
Endif

*********************************************************************************
*XCBBtl=ComboMAX (MPB)
* Define species group - CI variant
SpGroup        CBBSP
LP PP WB LM

If
SPMCDBH(2,CBBSP,0,5,999,0,999,0) GT .01
Then
Compute
*average diameter of the host >5 inches
_CBqmd16 = SpMcDBH(5,CBBSP,0,5,999,0,999,0)
```

```
*Proportion of host > 5 inches
_CBPrp16 = SpMcDBH(2,CBBSP,0,5,999,0,999,0) &
         / Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)

*values for susceptibility
_vba16 = LinInt(BBA,0,60,60,80,80,120,120,999,.1,.1,1,1,2,2,3,3)
_vqmd16 = LinInt(_LPqmd10,0,6,6,8,8,999,1,1,2,2,3,3)&
        + LinInt(_PPqmd10,0,6,6,8,8,999,1,1,2,2,3,3)&
        + LinInt(_LMqmd10,0,6,6,8,8,999,1,1,2,2,3,3)&
        + LinInt(_WBqmd10,0,6,6,8,8,999,1,1,2,2,3,3)
_vSUS16 = _vqmd16 * _vba16 * _CBPrp16
XCBBtl = LinInt(_vSUS16,0,1.2,1.2,2,2,3,3,4,4,999,1,1,1.5,1.5,2,2,2.5,2.5,3,3)

************************************************************************************
*XSBES = Spruce Beetle in Engelmann Spruce
If
_ProESBA GT .01
Then
Compute
*average diameter of the host >10 inches
_ESqmd10 = SpMcDBH(5,ES,0,10,999,0,999,0)

*Proportion of host > 10 inches
_ESPrp10 = SpMcDBH(2,ES,0,10,999,0,999,0) / Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)

*values for susceptibility
_vba10 = LinInt(BBA,0,60,60,100,100,150,150,999,.1,.1,1,1,2,2,3,3)
_vqmd10 = LinInt(_ESqmd10,0,12,12,16,16,999,1,1,2,2,3,3)
_vSUS10 =  _vqmd10 * _vba10 * _ESPrp10
XSBES = LinInt(_vSUS10,0,1.2,1.2,2,2,3,3,4,4,999,1,1,1.5,1.5,2,2,2.5,2.5,3,3)

************************************************************************************
* Define species group of whitebark pine and limber pine - CI variant
SpGroup       WBLMSP
WB LM

COMPUTE            0
*WBBtl=Whitebark Pine/Limber Pine (MPB)
If                 0
SpMcDBH(2,WBLMSP,0,5,999,0,999,0) GT .1
Then
Compute           0
*average diameter of the host >= 5 inches
_WBBqmd2 = SpMcDBH(5,WBLMSP,0,5,999,0,999,0)

*Proportion of host >= 5 inches
_WBPrp14 = SpMcDBH(2,WBLMSP,0,5,999,0,999,0) &
         / Max(SpMcDBH(2,All,0,.1,999,0,999,0),1)

*values for susceptibility
_vba14 = LinInt(BBA,0,25,25,45,45,60,60,999,.1,.1,1,1,2,2,3,3)
_vqmd14 = LinInt(_WBqmd14,0,7,7,10,10,999,1,1,2,2,3,3) &
        + LinInt(_LMqmd14,0,7,7,10,10,999,1,1,2,2,3,3)
_vSUS14 = _vqmd14 * _vba14 * _WBPrp14
XWBBtl  = LinInt(_vSUS14,0,1.2,1.2,2,2,3,3,4,4,999,1,1,1.5,1.5,2,2,2.5,2.5,3,3)


End
Endif
************************************************************************************
* End of R4-SSRS-FVS_CI_v2.kcp                                                     *
************************************************************************************
```